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U.H.F. scatter propagation across the English Channel

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UHF SCATTER PROPAGATION ACROSS THE ENGLISH CHANNEL

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1. Introduction

The problem of providing a u.h.f. colour television link to the Channel Islands has been studied for a number of years. Extensive recordings have been made on Guernsey, Alderney and the Cotentin peninsula[1] of the field strengths of a variety of mainland transmitters. The use of an s.h.f. link between the Isle of Purbeck and Alderney for both television and telephony has also been studied by the Home Office.

In 1974 the IBA (who are owners of the Channel Islands sites under a BBC/IBA site sharing arrangement) and the BBC decided that the link should be by the reception of Stockland Hill (Devon) at an existing site on Alderney, with an s.h.f. link from Alderney to the transmitting station on Jersey (Fremont Point). It was thought, however, that the long propagation path over the sea could adversely affect both the quality of a colour television signal and the receiving signal directivity which could be maintained. The latter aspect only is treated in this report.

Reception on Alderney is expected to be marred for a small proportion of the time by co-channel interference (c.c.i.). Table 1 shows those stations which are most likely to cause interference. The table also shows the protected field strength (p.f.s.) predicted for 99% time assuming no receiving aerial directivity. If the field strength of the wanted signal did not vary the required receiving aerial directivity would be given by the difference between the protected field strength and the wanted signal strength. However, the wanted signal is also a time-variant function, exhibiting both slow and rapid variations, so that a knowledge of the cross-correlation between wanted and unwanted signals is needed to deduce the receiving aerial directivity required. In order to give an indication of the requirements the last column of Table 1 shows the aerial directivity needed to protect the median value of the wanted signal. It may be seen that the greatest protection is required for that station (Kippure, Eire) which has the smallest angle to the wanted station (Stockland Hill). It was for this reason that concern was felt regarding the effects of scattering from the sea surface.

Fig. 1 shows the relative directions of the wanted and some unwanted stations. Since the interfering stations are likely to be of significant strength for only a few days in a year, a direct measurement using them would have taken an inordinately long time. In any case Kippure and Cancale were not yet commissioned. It appeared however that the effects of scatter propagation on the Kippure signal could be assessed by setting up a deep aerial null in the direction of Stockland Hill and having the principal aerial responses 7° away from this direction. The results of this experiment would not necessarily be applicable to the much larger scattering angle appropriate to Crystal Palace. Accordingly a second experiment was initiated in which signals from Rowridge, scattered through a similar angle into an aerial pointing towards Stockland Hill, were measured. The results of these experiments can be applied to other stations on intermediate bearings as well as to Crystal Palace. Some of the remaining stations in Fig. 1 involve scattering through angles nearer to 180°. In these cases there will be some screening by local terrain of the sea immediately in front of the receiving aerials so that the danger of interference by scattering seemed less great. Cancale, however, is much nearer than the other interfering stations and its

TABLE 1

Station	Relative Bearing, degrees	99% time p.f.s. with omni-directional aerial, dB (μV/m)	Column 3 minus median wanted f.s. dB
Kippure	7°	103	38
Crystal Palace	65°	102	37
Cancale	163°	100	35
Rouen	127°	94	29
Nantes-Ht-Goul	163°	87	22
Goes	91°	87	22
Lelystad	85°	81	16
Bourges-Neuvy	154°	79	14
Bilsdale	35°	79	14
Mynydd Machen	11°	71	6
Rhondda	6°	68	3
The Wrekin	24°	65	0
Kilvey Hill	1°	64	−1

Note (1) The incidence of c.c.i. is not the same on all channels; the figures are given for the worst channel.

(2) For stations not yet built, the full power and aerial height agreed internationally have been assumed. In the case of Kippure it is likely that the actual power will be at least 10 dB below that assumed.

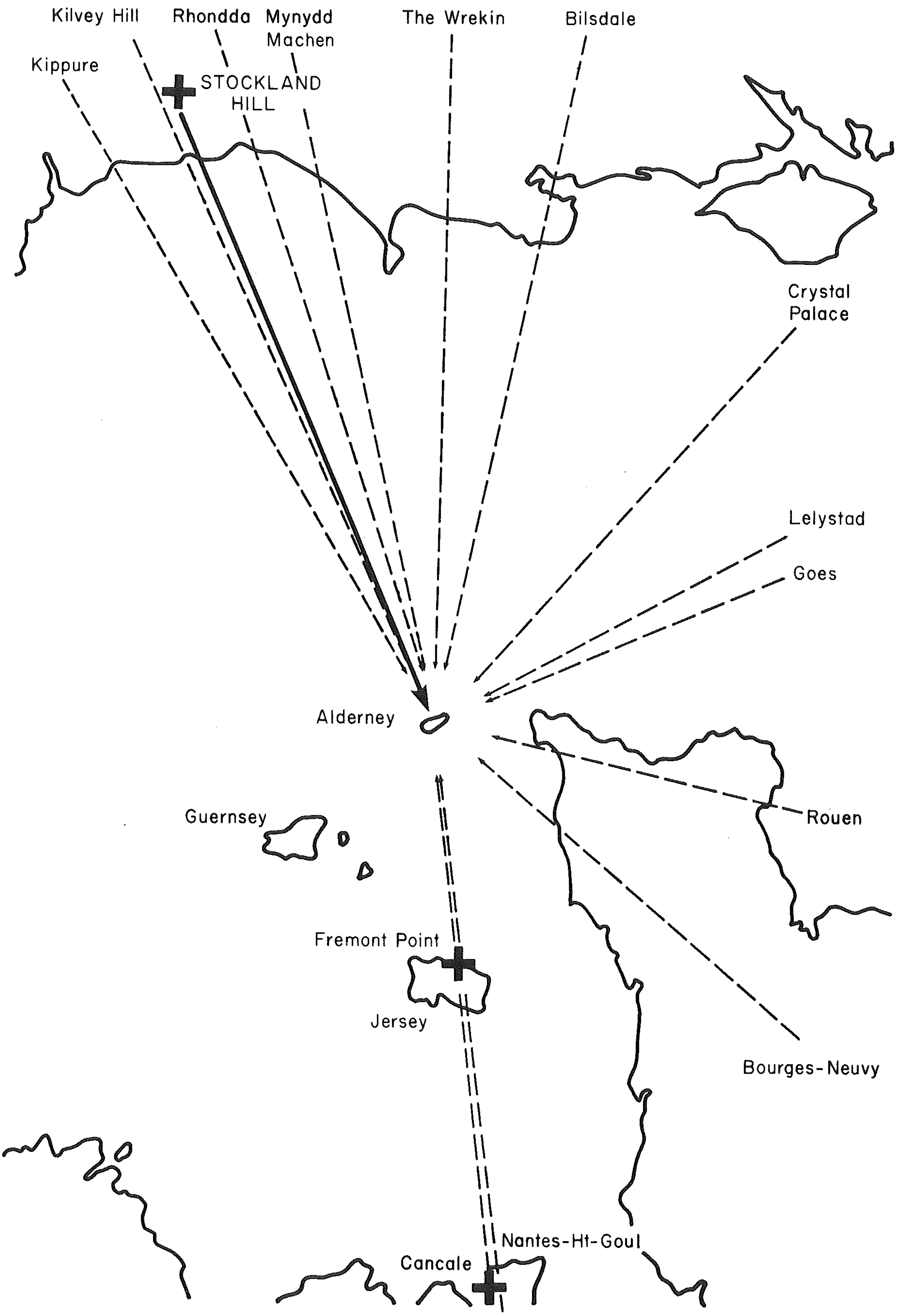

Fig. 1 - Principal sources of co-channel interference at Alderney

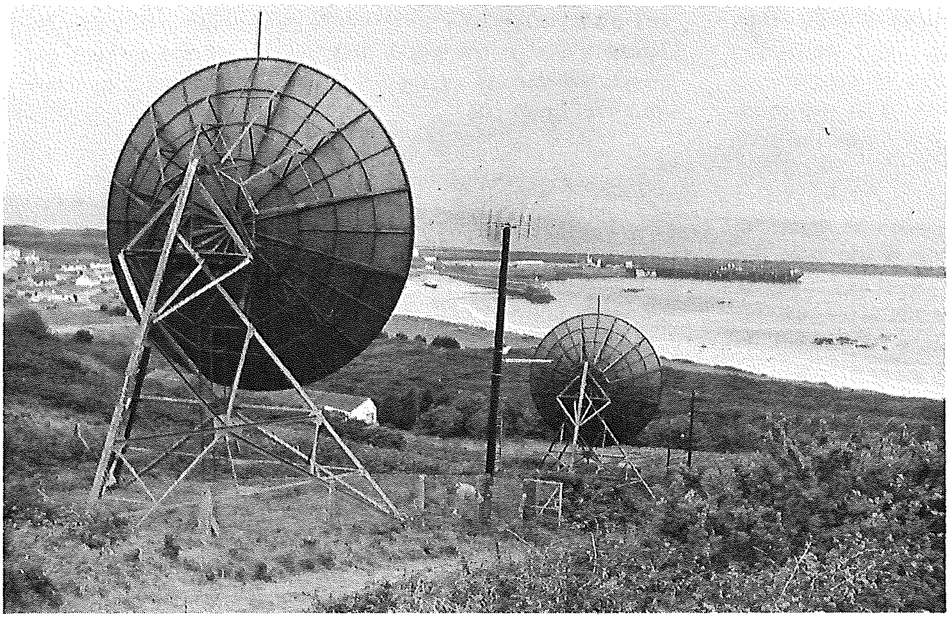

Fig. 2 - General view of paraboloidal aerials

interference will be virtually continuous so that it may cause serious trouble on the one channel it affects (BBC-1).

2. Existing and proposed aerial installations on Alderney

The highest ground on Alderney is adjacent to the airport and is not available for large aerial installations. The site actually used is some 24 m lower and is on a north-west facing slope overlooking the harbour. A 30 m tower carries two large v.h.f. arrays* pointing towards Chillerton Down (Isle of Wight) as well as the s.h.f. link aerials directed towards Fremont Point (Jersey). The v.h.f. aerials most frequently used are two 9·1 m diameter paraboloidal reflector aerials pointing towards Stockland Hill.[2] These aerials are sited some distance away from the tower in a shallow gully so that they are screened by local terrain from signals arriving from directions in the arc 020°–270° ETN. Fig. 2 shows a photograph of these aerials.

The final u.h.f. installation is expected to comprise one adaptive and two fixed aerial systems mounted on the tower together with one or both of the paraboloidal reflectors. It will be necessary to use a combination of these aerials in diversity so that it is desirable that each has adequate directivity.

The aerials look out over the harbour and breakwater and various potential scattering sources may be noted:

(i) Shipping in Braye Harbour. The line of reception passes near to an area of activity.

(ii) Mobile cranes maintaining the breakwater. This work is only occasional.

(iii) Seas breaking on the breakwater. It is commonplace for spray to rise 10 m above the breakwater even in relatively calm conditions. The breakwater has an angle of depression of only 2·5 degrees from the upper paraboloidal aerial.

(iv) The signal path passes near the small island of Burhou and other rocks. Between Burhou and Alderney an overfall occurs at certain states of the tide.

(v) Large oil tankers and other shipping pass at a distance of 10 – 20 km.

(vi) Aircraft using the local airport and passing over the signal path.

(vii) The open sea.

(viii) Turbulence in the atmosphere.

The effects of aircraft and possibly of shipping could be recognised on occasions when an operator was present. There did not appear to be a strong dependence on the state of the tide. There was an association with wind direction and this is discussed in more detail in Section 7.

3. Sea scatter

Diffuse reflection (scattering) from the surface of the sea is well known and has been studied by a number of investigators (see Reference 3, Chapter 18 and bibliography). Much of the work relates to back-scatter, i.e. scattering through a large angle and at frequencies in use for radar. Some observations of large-angle scattering from the sea were made on the Channel coast at v.h.f.[4] The scattered signal had a maximum relative amplitude of –23 dB which varied at about 0·03 Hz and produced a 0·7 Hz beat with the direct signal. (For a u.h.f. signal the beat would be expected to be about three times faster.) Observations of forward scatter at u.h.f. have been made at a number of locations in connection with an investigation of tidal fading.[5] The relative amplitude of the diffusely-scattered component was generally in the range −20 dB to −30 dB. There was no regular beat as with backscatter; the amplitude of the resultant signal varied randomly with a frequency of up to about 1 Hz. As the maximum response of the recorder was around this value the true maximum was possibly higher.

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* These have since been removed.

In all the above cases the signal source was above the horizon so that line-of-sight signal paths apply. In the present application, however, the wanted signal and many of the interfering signals come from stations which are beyond the radio horizon. This creates a difficulty for any simple theoretical approach in that the grazing angle γ is zero so that application of the Rayleigh criterion for specular reflection

$$h < \frac{\lambda}{8 \sin \gamma} \qquad (1)$$

indicates that the surface is effectively smooth for all heights of surface irregularity, h. However, it may be argued that conditions of anomalous propagation are equivalent to a virtual source appearing above the horizon so that a brief theoretical study of sea scatter is justified. This is not to be taken to deny the existence of other scattering mechanisms in the troposphere which may contribute to, or dominate, the observations. Such mechanisms are referred to later.

4. Theoretical study of sea scatter

Several theoretical models for the study of various aspects of sea scatter have been formulated.[3] A surface having periodic irregularities, such as sinusoidal undulations, is amenable to analysis. However the periodicity of the sea is not constant; there may be several periodicities present, coming from different directions, and all continually changing with wind and tide. The alternative is a statistical approach, treating the sea as a randomly rough surface, even though this may underestimate the peak amplitude of reflections from the actual surface when the periodicity is favourable in wavelength and direction.

We assume first that the surface is described by the statistical distribution of its deviation from a mean level. Consider the one-dimensional case when the height of the surface is given by a variable $\zeta(x)$ and is constant in the y direction. The most important distribution typical of a rough surface is the normal distribution. Let the mean value

$$\overline{\zeta} = 0$$

and the standard deviation be σ. Then $\zeta(x)$ assumes values z with a probability density

$$W(z) = \frac{1}{\sigma\sqrt{(2\pi)}} \; e^{-z^2/2\sigma^2} \qquad (2)$$

The standard deviation σ describes the roughness of the surface. However the surface is not uniquely described by the distribution of ζ as this tells us nothing about the distances between the peaks and troughs of the surface, i.e. about the density of the irregularities. We need to know how two functions

$$\zeta_1 = \zeta(x_1)$$

$$\zeta_2 = \zeta(x_2)$$

are related in terms of the separation

$$\tau = x_1 - x_2$$

This is given by the autocorrelation coefficient

$$C(\tau) = \frac{\overline{\zeta_1 \zeta_2}}{\zeta_1^2} \qquad (3)$$

For a normal distribution we may take

$$C(\tau) = e^{-\tau^2/T^2} \qquad (4)$$

where T is the correlation distance, for which $C(\tau)$ will drop to the value e^{-1}. Fig. 3 shows random surfaces with large and small values of T.

The surface is now defined by Equations (2) and (4) in terms of constants σ and T. It is sometimes convenient to work with the slope of the surface rather than the height above a mean level. If the slope ψ of a normal surface is defined by

$$\tan \psi = \zeta'(x) \qquad (5)$$

it may be shown[3] that the distribution of the slopes is given by

$$p(\psi) = \frac{T}{2\sigma\sqrt{\pi}\cos^2\psi} \exp\left(-\frac{T^2 \tan^2\psi}{4\sigma^2}\right) \qquad (6)$$

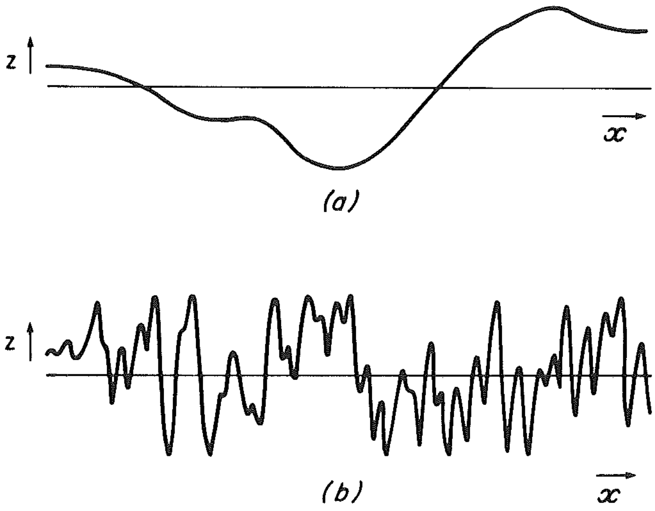

Fig. 3 - A random surface with
(*a*) large and (*b*) small correlation distance

Introducing the quantity β_o defined by

$$\tan \beta_o = 2\sigma/T \tag{7}$$

we have

$$p(\psi) = \frac{1}{\sqrt{\pi}\,\tan\beta_o \cos^2\psi}\exp\left(-\frac{\tan^2\psi}{\tan^2\beta_o}\right) \tag{8}$$

Now the surface of the sea is gently undulated, the slopes are mostly small and the correlation distance relatively large so that

$$2\sigma \ll T \tag{9}$$

We may therefore approximate the tangents by their arguments and Equation (8) becomes:

$$p(\psi) \simeq \frac{1}{\beta_o\sqrt{\pi}}\, e^{-\psi^2/\beta_o^{\,2}} \tag{10}$$

which is itself a normal distribution with standard deviation $\beta_o/\sqrt{2}$.

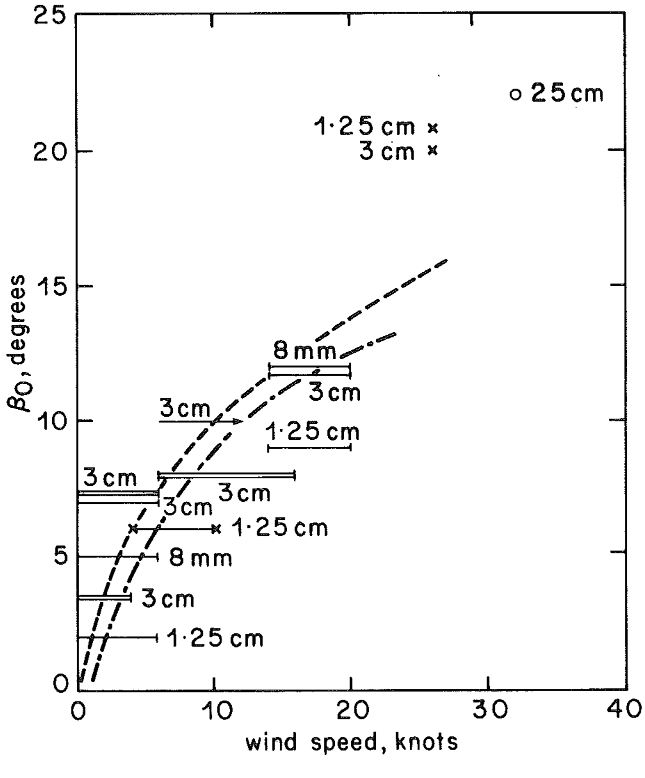

Fig. 4 - Experimental values of β_o as a function of the wind speed

——▸	Kerr (1951)	Radio (back-scatter) measurements
——	Grant and Yapplee (1957)	
× ×—×	Wilste (1957)	
o	MacDonald (1956)	
═══	Campbell	Optical measurements
— — —	Cox and Munk (1954)	
—·—	Schooley (1954) (upwind)	

The surface of the sea has been the subject of experimental investigations, both optically and at radio frequencies. To a first approximation the distribution of slopes has been found to be normal. Fig. 4, which is reproduced from Reference 3, Figure 18.6, shows some experimental values of β_o as a function of wind speed.

The concept of reflecting slopes or facets gives rise to the concept of the glistening surface, defined as that part of the surface which can participate in the reflection of waves for given positions of transmitter and receiver. The optical analogy of the sun setting over the sea makes the term clear. The angle subtended by the glistening surface is a measure of the angular spread of energy scattered from the surface. In order to calculate the boundary of the glistening surface an even simpler model will be assumed for the surface, namely that the distribution of reflecting facets is uniform up to the value β_o and zero beyond it. It may then be shown[3] that the boundary of the glistening surface when one terminal is at infinity takes the form

$$2\cos u = \frac{\cos\nu}{\cos\gamma} + \frac{\cos\gamma}{\cos\nu} - \tan^2\beta_o\,\frac{\sin\gamma + \sin\nu}{\cos\gamma + \cos\nu} \tag{11}$$

where u is angle to direction of the source

ν is the angle to the vertical

γ is the grazing angle.

In the case under consideration the grazing angle, γ, is tending to zero so that Equation (11) reduces to

$$2\cos u = \cos\nu + \frac{1}{\cos\nu} - \tan^2\beta_o\,\frac{\sin\nu}{1+\cos\nu} \tag{12}$$

A value for β_o may be determined from Fig. 4; since a mean wind speed of about 10 knots is found in the area, it is appropriate to put $\beta_o = 10^\circ$ in order to assess the extent of the phenomenon. Fig. 5 shows the result of the calculation for an aerial array on the tower at Alderney. The glistening surface extends quite close up to the receiving aerial, falling partly on land and partly on the sheltered water of Braye Bay. If we restrict consideration to that part of the glistening surface beyond the breakwater where the rough water starts, we find that the maximum angle subtended at the receiving angle is $\pm 1{\cdot}8^\circ$.

Now the mean absolute square of the reflection coefficient for the diffusely scattered component $\overline{|R_d|^2}$ is given by[3]

$$\overline{|R_d|^2} = \overline{|\rho_d|^2}\;R_o^{\,2} \tag{13}$$

where R_o is the reflection coefficient of the smooth surface and

$$\overline{|\rho_d|^2} = \frac{1}{2\pi\beta_o^{\,2}}\int_{\nu_1}^{\nu_2} u(\nu,\gamma)\cot\nu\,d\nu \tag{14}$$

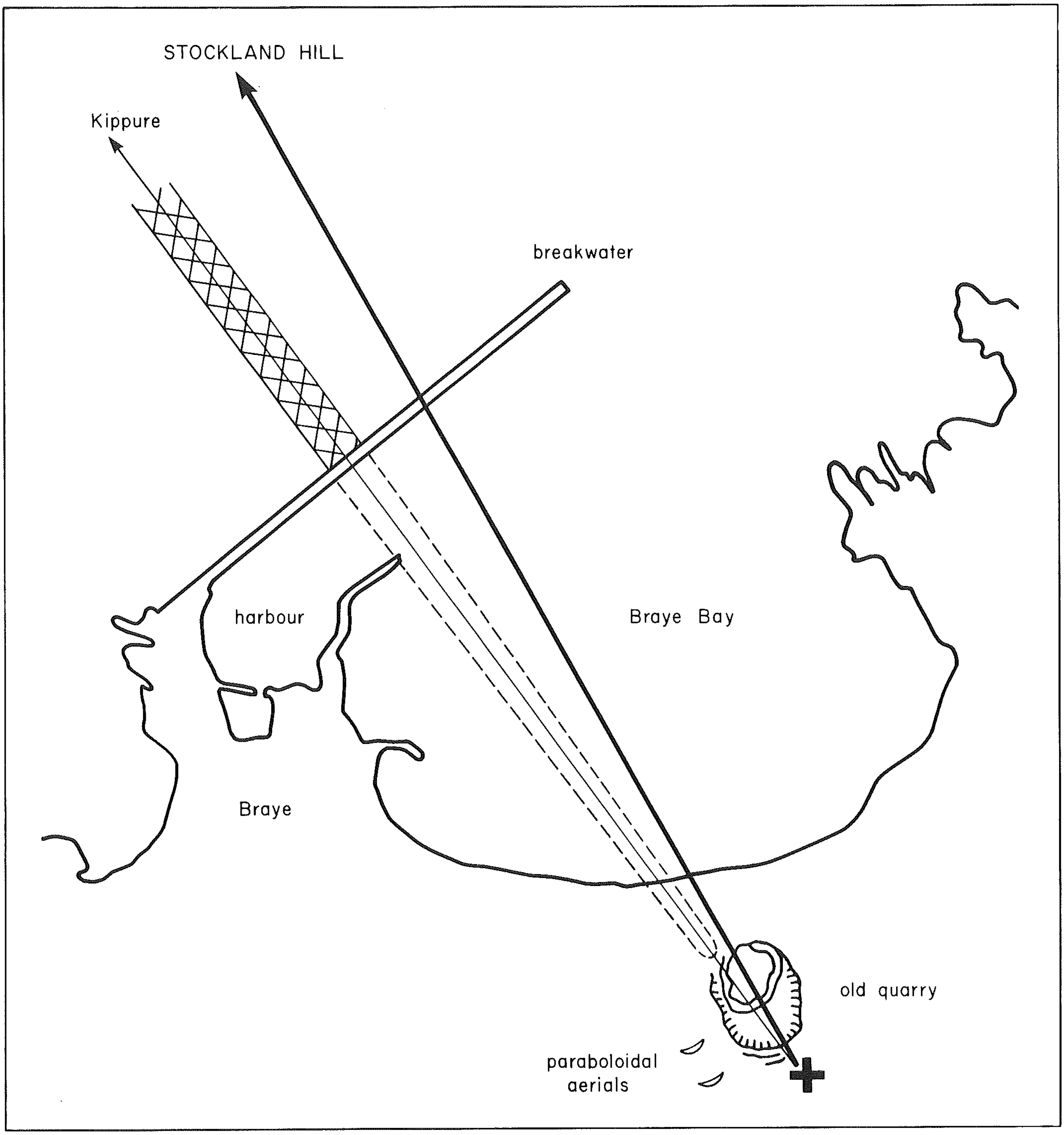

Fig. 5 - Extent of glistening surface for $\beta_o = 10°$

Performing this integration numerically over the surface defined above, we find

$$\overline{|\rho_d|^2} = 0{\cdot}24 \qquad (15)$$

For a smooth sea and a very small grazing angle, R_o is −1. Accordingly, by (13), the power reflection coefficient, $R_d{}^2$, is 0·24. However, the aerial directivity will suppress some of the scattered signal as well as the direct signal. For simplicity, let us assume that the aerial has directivity in the horizontal plane only (this is sufficiently true for the arrays on the tower and will be only slightly in error for the paraboloid aerials). Taking this into account we find that the power reflection coefficient is 0·013. In other words, the mean value of the scattered component of the signal picked up by the aerials is calculated to be −19 dB. Now this is the energy reaching the aerial by diffuse reflection off the sea when the aerial radiation pattern takes the form shown in Fig. 6. Owing to the simplicity of the model assumed (uniform distribution of slopes up to β_o and zero

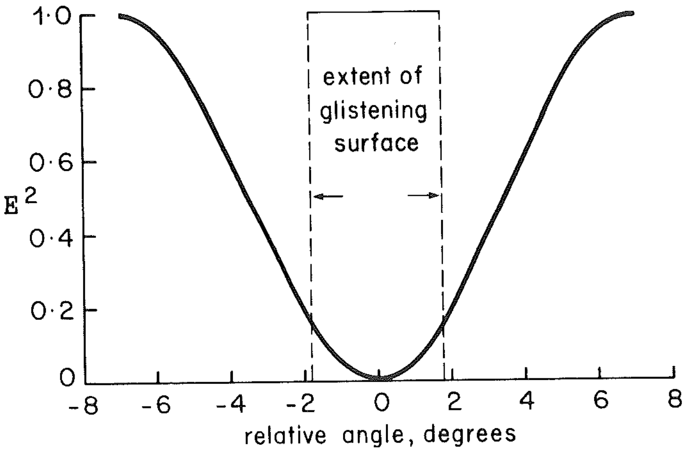

Fig. 6 - Suppression of scattered signal by an aerial minimum

beyond it) the amount of scattered energy will have been over estimated.

As the wind rises and the maximum wave slope increases, the lateral extent of the glistening surface increases so that the aerial suppression gets less. At the same time the total energy scattered towards the aerials reduces so that the scattered energy picked up by the aerials rises only slowly.

Although the theory given above contains many approximations, it is useful in setting orders of magnitude for sea-scatter. In applying the results to the propagation path from Stockland Hill to Alderney, however, it must be borne in mind that the surface of the sea is not the only possible scattering mechanism. Since the propagation path extends beyond the radio horizon, it is possible that scattering in the troposphere, e.g. by turbulence, may be appreciable or even dominant. Since the major concern was with the behaviour of a particular propagation path, no attempt was made to distinguish between the two scattering mechanisms.

5. Measurements of scattering

Two series of measurements were carried out in order to determine the characteristics of scattering through angles of 7° and 57°. These angles are approximately the scattering angles in the horizontal plane for interference from Kippure and Crystal Palace.

5.1. Scattering through a 7° angle

Two log-periodic aerials were rigidly mounted side-by-side in the horizontal plane with the spacing required to give a null 7° away from the main beam when the signals

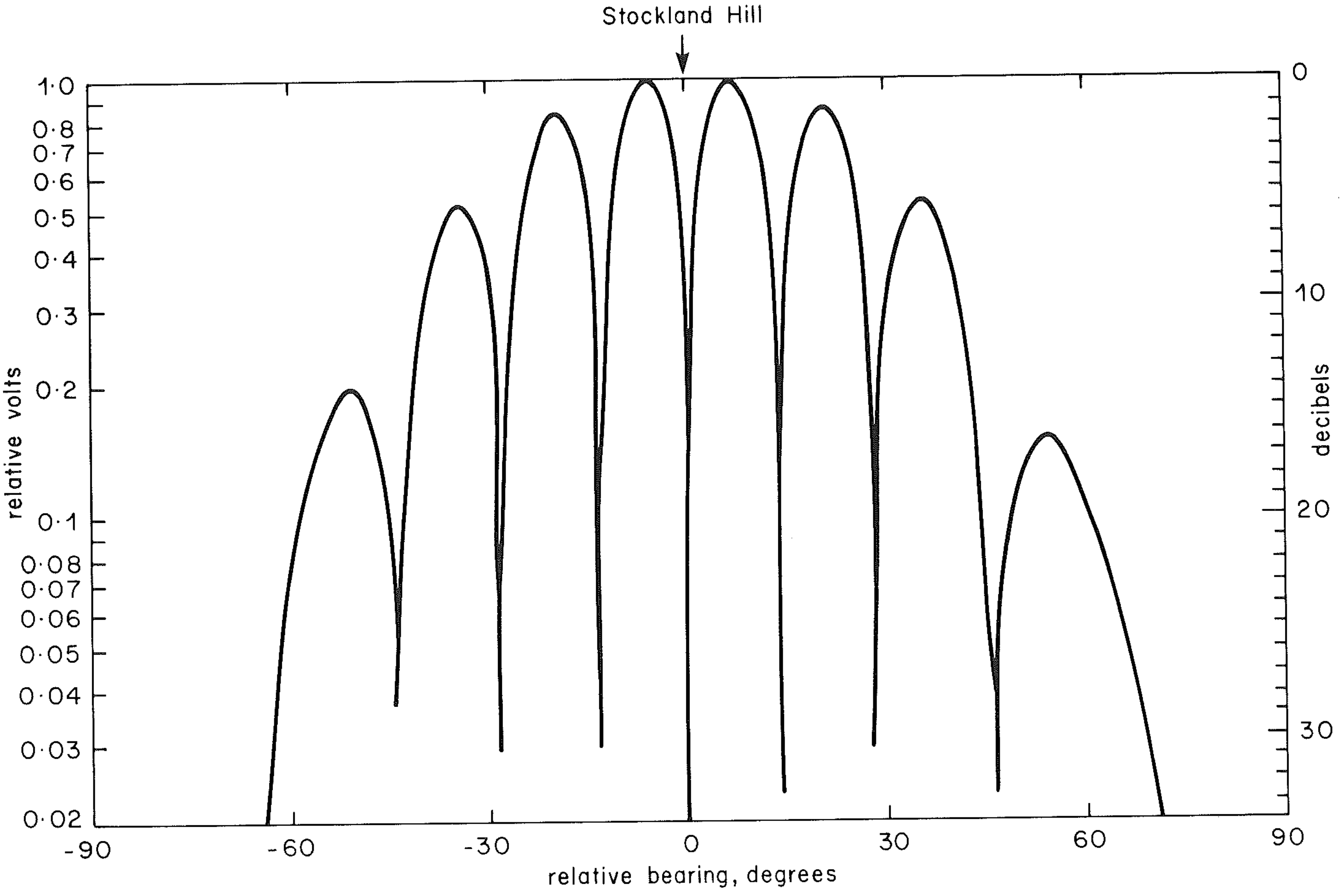

Fig. 7 - Horizontal radiation pattern of aerial in 'difference' condition (In the 'sum' condition the positions of the maxima and minima are interchanged)

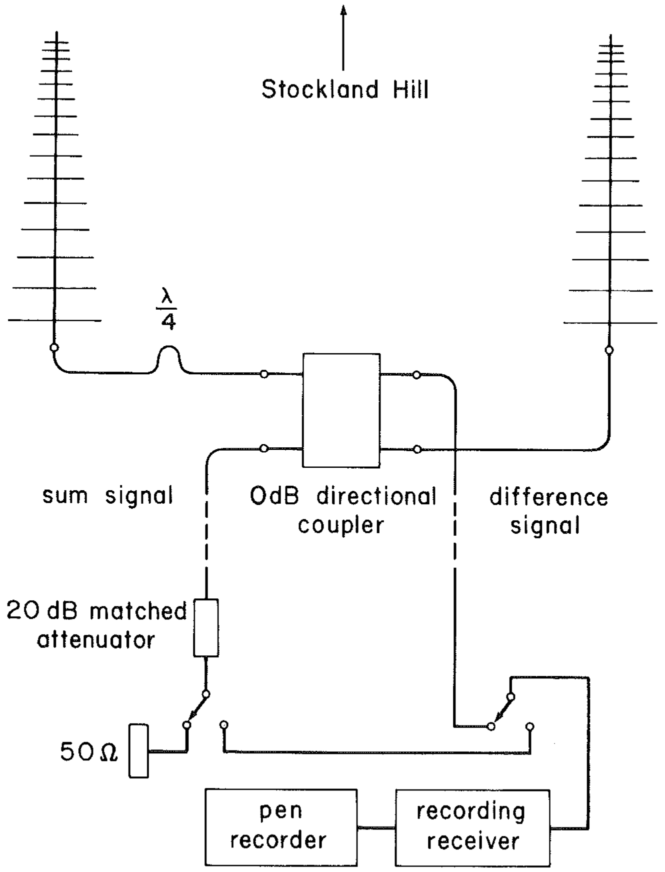

Fig. 8 - Experimental arrangement for measuring scattering through 7°

were added in phase. Arrangements were made to measure this signal and also the difference signal. For the latter condition, care was taken to obtain a deep null by making small adjustments to the relative amplitudes of the signals from the two aerials. Fig. 7 shows the measured horizontal radiation pattern of the arrangement in the 'difference' condition (in the 'sum' condition the radiation pattern is similar but with the maxima and minima interchanged in position). When the aerial was set up on site in the difference condition it was found that the depth of null obtainable was limited by short period variations of the signal level which presumably resulted from scattering. Accordingly the aerial was set up to give the lowest mean signal level, averaged over a few minutes. Assuming that this setting was close to the optimum, a comparison of sum and difference signals gives the suppression obtainable with this aerial in the presence of scattering. For the measurements, a recording receiver was switched between the sum and difference aerials in the arrangement shown in Fig. 8.

Measurements took place over the period 5th June 1975 to 2nd September 1975. Although this period is not typical of the year as a whole, it does cover the season when anomalous propagation, and therefore co-channel interference, is most prevalent. As it was not practicable to run the chart recorder fast enough to resolve rapid fading, the measurements relate to the average level of the signals over a seven-minute period. The observed distribution of aerial directivity is shown in Fig. 9 and is based on 421 sample measurements over the period. A service aerial would be expected to have a median value of rejection up to 3 dB greater than that shown in Fig. 9; this is because in the experiment the scattered power was received on two equal lobes on either side of the null whereas the service aerial will have a single lobe. It may be noted that the observed

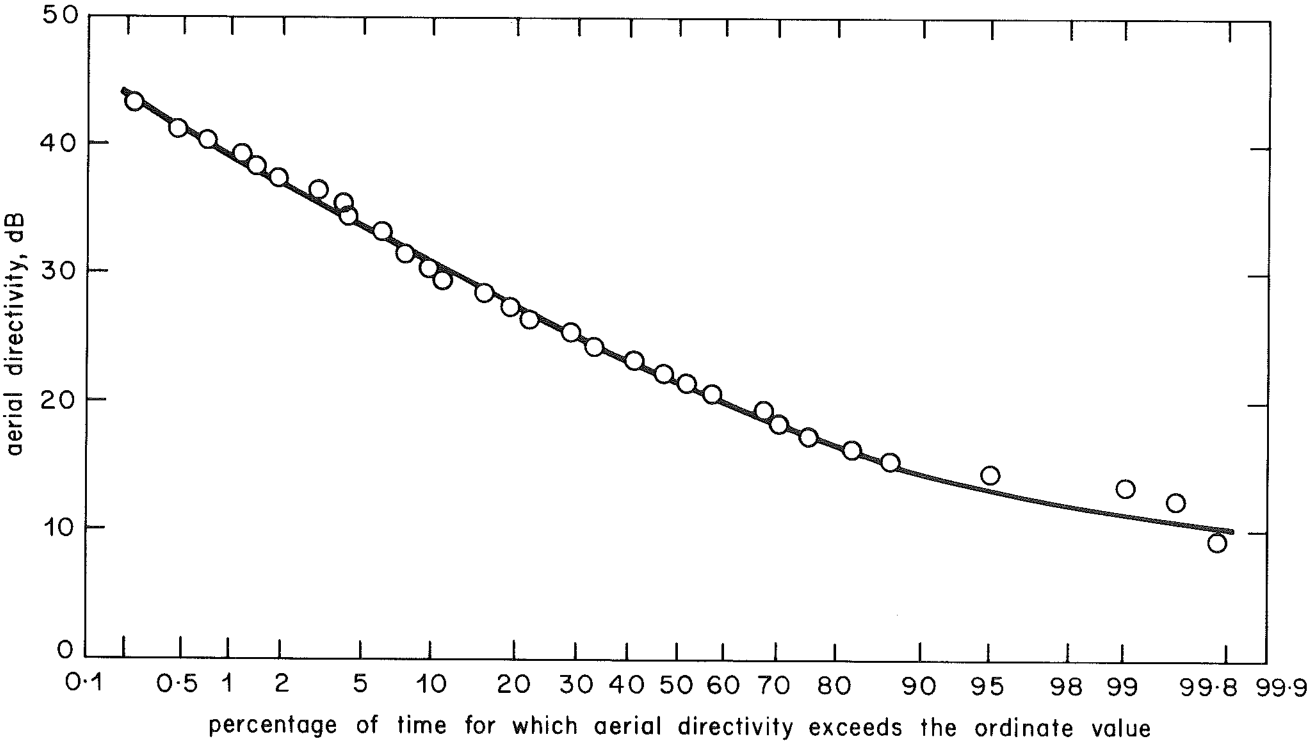

Fig. 9 - Directivity attainable with 7° scattering

median value is 5 dB below the level calculated from the simple theory of Section 4.

The coefficient of correlation between the aerial directivity and the level of the wanted signal was calculated to be 0·23, indicating that there was some tendency for high directivity to occur with high signal strength. This result is to be expected since periods of high signal strength often occur when air and sea are still and therefore not scattering to any appreciable extent.

5.2. Scattering through 57°

These measurements were made using one of the paraboloidal reflector aerials aligned on Stockland Hill to receive signals from Rowridge (Isle of Wight), the difference in bearings being 57°. Rowridge has a different channel group from that of Stockland Hill and so is not in itself a source of interference. It was chosen for the measurements because its signals were always measurable and because its bearing differs from that of Crystal Palace by only 8°. In order to carry out the measurements it was necessary to fit a u.h.f. feed to the paraboloid without disturbing the v.h.f. feed carrying IBA programme. In the most convenient arrangement, the u.h.f. aerial was fitted slightly to one side of the axial boom, so that the latter produced some distortion of the feed radiation pattern. Part of the radiation pattern of the paraboloid was measured on the breakwater, giving the result shown in Fig. 10. Although it was impracticable to continue measurements round to the angles of interest, it seemed likely that reasonable directivity would be obtained. Signals from the directions of Rowridge and Crystal Palace will be further attenuated by intervening terrain, so that it was hoped that the directivity rejection would be quite good. The results obtained confirm that this was so.

The measurements took place over the period February – May 1975. The observed distribution of aerial directivity is shown in Fig. 11. This is based on 291 samples of the levels of scattered and control signals averaged over a seven-minute period. The coefficient of correlation between the aerial directivity and the level of the wanted signal was found to be –0·05. This is sufficiently small for it to be reasonable to assume that the two variables are uncorrelated.

The results for the paraboloidal reflector aerial shown in Fig. 11 exhibit a smaller range of variation compared with those for the spaced aerials (Fig. 9). As is to be expected, the discrimination of the more directional aerial is less subject to scattering mechanisms.

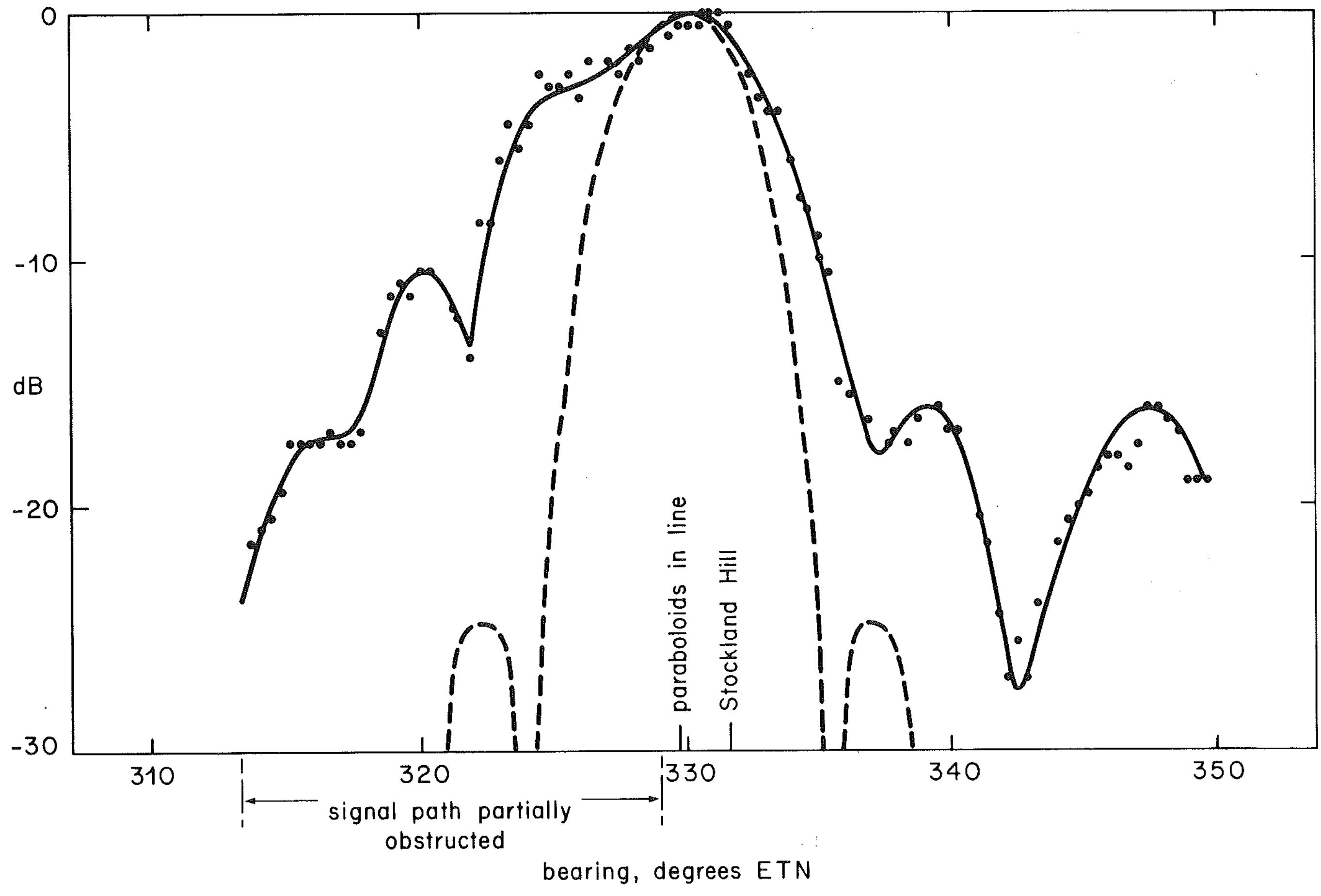

Fig. 10 - Measured h.r.p. of paraboloidal aerial with temporary u.h.f. feed

——— Measured pattern channel 29 – – – – Calculated pattern assuming tapered illumination

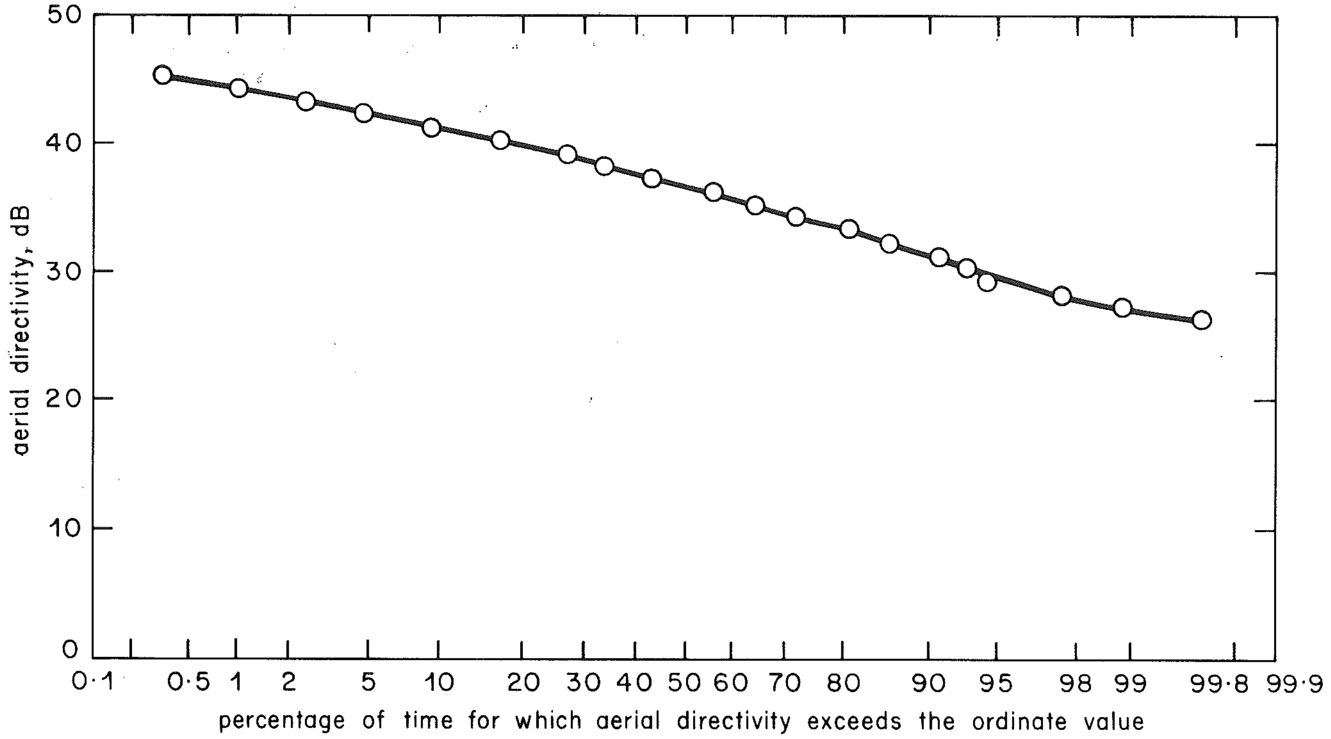

Fig. 11 - Directivity attainable with 57° scattering

6. Assessment of c.c.i.

6.1. Method

The distributions of aerial directivity shown in Figs. 9 and 11 do not depart very much from straight lines, indicating that the distributions are approximately log-normal, i.e. the distributions are gaussian when the values are expressed in decibels. The distributions of signal strengths of the wanted signal, and of an interfering signal, are not in general log-normal. However, it is desirable only to assess the level of interference for the small percentage

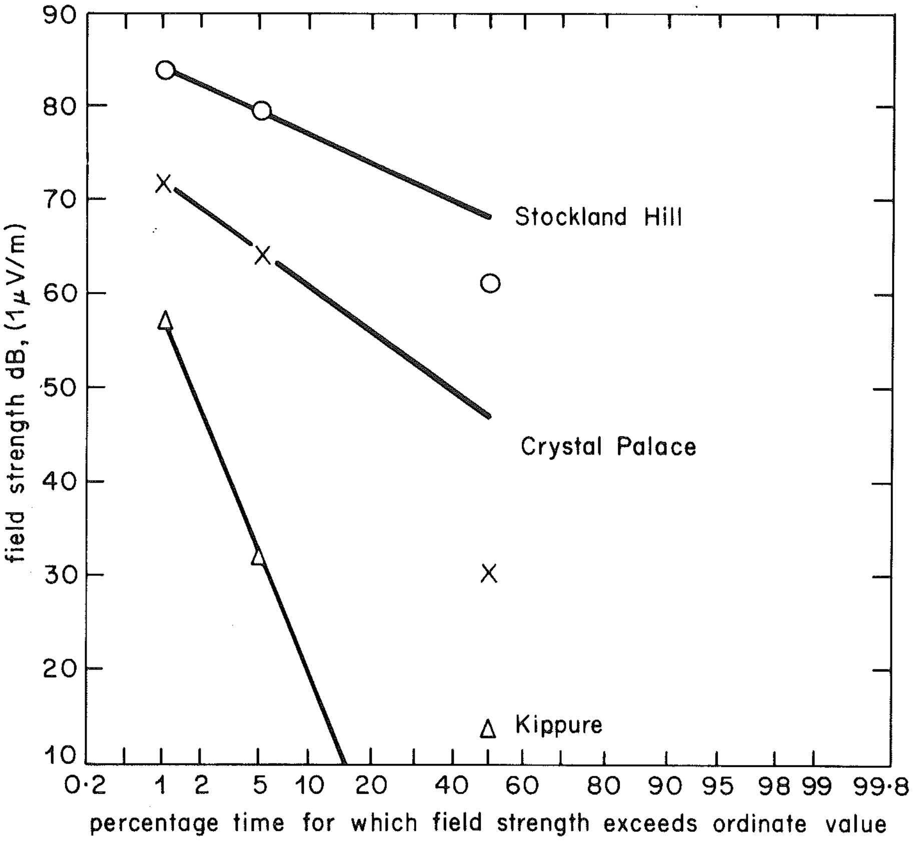

Fig. 12 - Field strength distributions with wanted and unwanted transmitters

of time when it is relatively high. It is therefore necessary only to fit a log-normal curve to the 'high' end of the signal distribution and this can be done with good accuracy. Fig. 12 shows straight lines fitted to the 1% and 5% measured field strengths of the wanted signal from Stockland Hill and to the 1% and 5% predicted field strengths of the interfering signals from Crystal Palace and Kippure.

It can be inferred from Fig. 12 and the median values shown that the assumption of log-normal distributions will yield slightly pessimistic results with regard to interference from Crystal Palace. The predicted field strengths from Kippure for the greater percentage of time are very low compared to the wanted signal and the log-normal distribution can be used with confidence.

Let the wanted signal have a mean value $\overline{X}$, in dB relative 1μV/m, and a standard deviation of σ_x. Similarly let the interfering signal have a mean value $\overline{Y}$ with standard deviation σ_y and the rejection of it afforded by the aerial a mean value of $\overline{Z}$ and a standard deviation σ_z.

It may be shown, using the trivariate normal distribution,[6] that the median value of protection of the wanted signal against c.c.i. is:

$$\overline{P} = \overline{X} - \overline{Y} + \overline{Z}$$

and the standard deviation of the protection is given by

$$\sigma_p{}^2 = \sigma_x{}^2 + \sigma_y{}^2 + \sigma_z{}^2 \pm 2A\sigma_x\sigma_y \pm 2B\sigma_y\sigma_z \pm 2C\sigma_z\sigma_x$$

where $A = \rho_{xy} - \rho_{yz}\rho_{zx}$

$B = \rho_{yz} - \rho_{zx}\rho_{xy}$

$C = \rho_{zx} - \rho_{xy}\rho_{yz}$

ρ_{xy} etc. are the coefficients of correlation between pairs of variables taken alone. The signs of the coefficients A, B, C are the products of the signs of the variables $\overline{X}$, $\overline{Y}$, $\overline{Z}$.

The value of ρ_{xy} is thought to be fairly high since both wanted and unwanted signals propagate from over the horizon; a value of 0·5 will be assumed. ρ_{zx} is determined from the measurements. ρ_{yz} is not known; it is unlikely to be negative or highly positive and so trial values of 0, and +0·5 were assumed. It was found that the standard deviation of protection differed only slightly between these cases (less than 3 dB).

6.2. Interference from Kippure

The relevant parameters are given in Table 2. The statistics of the wanted signal are known from long-term measurements. Those for the interfering signal are from a computer prediction.[7] A pessimistic value of ρ_{yz} is used.

The value of $\overline{P}$ is found to be 121 dB with a standard deviation, σ_p, of 31·9 dB. The protection exceeded for 99% time is $\overline{P} - 2{\cdot}33\sigma_p$ and is found to be 46·7 dB. The protection ratio normally required for zero offset c.c.i. is 45 dB and this will be exceeded for the percentage time corresponding to $(\overline{P} - 45)/\sigma_p$ standard deviations, or 99·1% time in this case.

TABLE 2

Parameter	Median dB	Standard Deviation dB	Coefficient
Wanted signal, *X*	68($\overline{X}$)	7(σ_x)	–
Interfering signal, *Y*	–27($\overline{Y}$)	36(σ_y)	–
Aerial rejection, *Z*	26($\overline{Z}$)	6(σ_z)	–
ρ_{xy}	–	–	0·5
ρ_{yz}	–	–	0·5
ρ_{zx}	–	–	0·23

The above figures assume that the station at Kippure will be built to the full power permitted under international agreement. It is, however, likely that the e.r.p. actually used will be at least 10 dB lower than this. The required protection ratio will then be achieved for 99·6% of the time.

6.3. Interference from Crystal Palace

As before a value for ρ_{xy} of 0·5 is assumed. Experimentally ρ_{zx} was found to be zero and so it seems reasonable to put ρ_{yz} to be zero also. The expression leading to σ_p then becomes

$$\sigma_p{}^2 = \sigma_x{}^2 + \sigma_y{}^2 + \sigma_z{}^2 - 2\rho_{xy}\sigma_x\sigma_y$$

The parameters are given in Table 3.

TABLE 3

Parameter	Median dB	Standard Deviation dB	Coefficient
Wanted signal, *X*	68 ($\overline{X}$)	7 (σ_x)	–
Interfering signal, *Y*	47 ($\overline{Y}$)	10·5 (σ_y)	–
Aerial rejection, *Z*	37 ($\overline{Z}$)	4 (σ_z)	–
ρ_{xy}	–	–	0·5

The mean value of protection ratio is found to be 58 dB with a standard deviation of 10 dB. The protection ratio exceeded for 99% time is $\overline{P} - 2{\cdot}33\sigma_p$ or 35 dB. The transmissions have normal offset so that a protection ratio of 30 dB is desired. This will be exceeded for the percentage time corresponding to $(\overline{P} - 30)/\sigma_p$ standard deviations or 99·75% time.

7. The effect of the wind

During the course of the measurements a record was kept of observations of wind speed and direction at the nearest available monitoring station. This was on the island of Guernsey, some 40 km south-west of Alderney. Fig. 13 shows the aerial directivity plotted against wind speed for the measurements with a 57° scattering angle. There appears to be negligible correlation between the variables. Fig. 14 shows the aerial directivity plotted against the wind direction and in this case there does appear to be

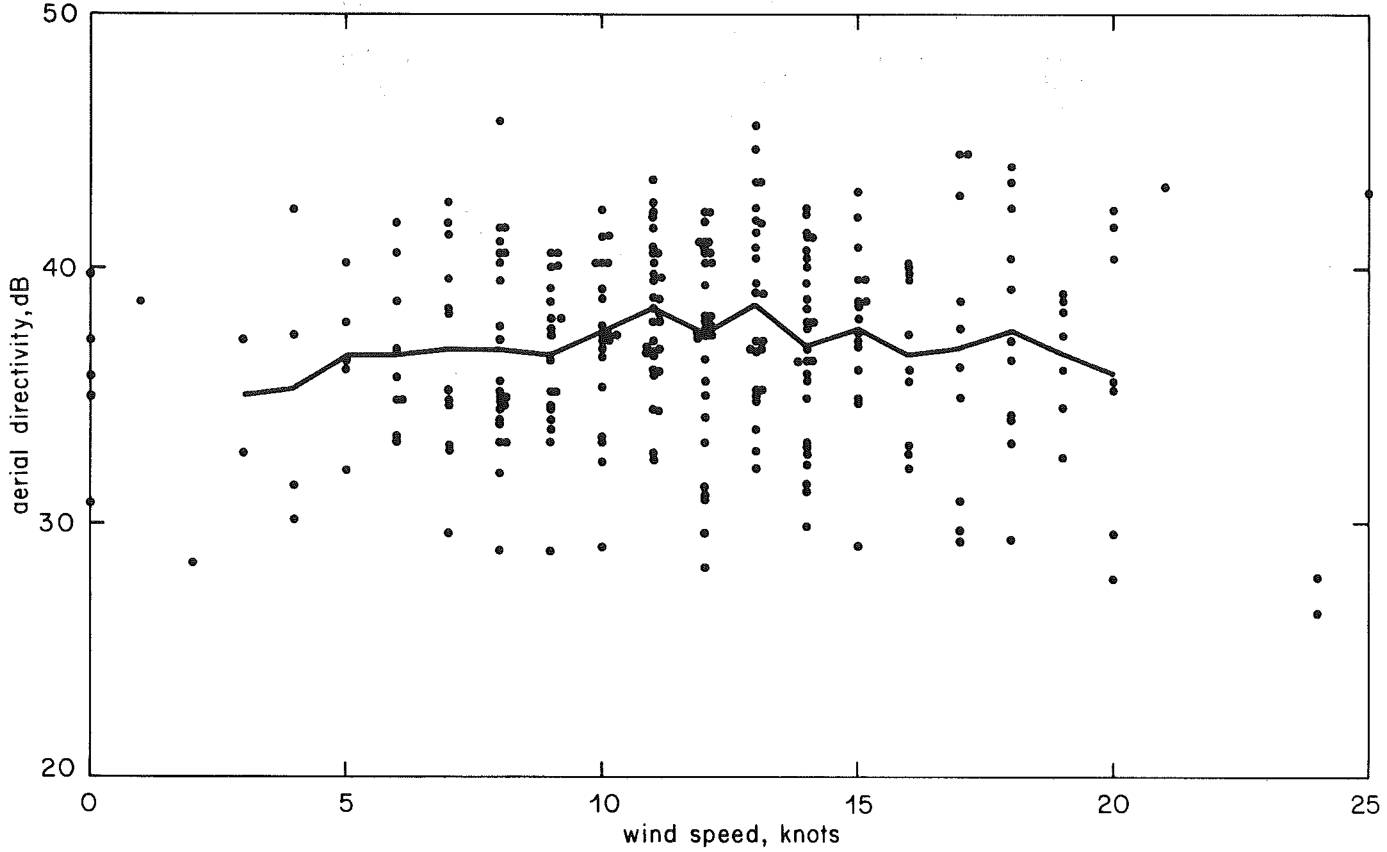

Fig. 13 - Effect of wind speed on aerial directivity

——— Mean value

some interdependence. An easterly wind would appear to give a lower aerial directivity than a westerly one. Some such effect might be expected with signals scattered from waves on the sea. However, it might also be argued that these two wind directions are associated with different weather patterns and that the scattering could be tropospheric. In either case it is surprising that the speed of the wind appears to have no influence on the aerial directivity.

8. Conclusions

Measurements have been made to determine in statistical terms the aerial directivity likely to be achieved with fixed aerials in the directions of two potential sources of interference to the u.h.f. re-broadcast link to the Channel Islands. It has been shown in both instances that the interference will be troublesome for only a small percentage of time. In addition, there are various other potential sources of interference to this link. The work described in the report has been used to assess the likely effect of these also and to give an overall assessment of interference levels. It is found that while two of the channels will have interference to about the degree expected on a typical mainland link, the other two are likely to be somewhat worse. Some amelioration will result from the use of diversity techniques to limit the depth of fading of the wanted signal and this aspect is currently being studied. It will also help to design aerial arrays with broad minima where this is possible.

One solution that has been proposed is the use, instead of a fixed aerial, of an adaptive aerial capable of steering nulls into a source of interference. Two points may be noted. First, although a null may be generated in the direction of the interfering station, a residue of interference will be picked up by scattering into the aerial main beam. Given sufficient degrees of freedom, the adaptive aerial will attempt to cancel out this interference by accepting an equal level from a different direction. Assuming that scattering is tropospheric, the scattering volume will be some tens of kilometres from the receiving installation so that the path difference between direct and scattered signals will be large and the delay significant. Thus the 'nulling' will be narrow-band and limited in extent. Secondly, the rate of response of an adaptive system is determined by various design factors. A system capable in principal of nulling several sources of interference simultaneously on four channels will inevitably react rather slowly to changes in the interference pattern. The response is likely to be at least an order of magnitude too slow to deal with the normal fluctuations of the scattered signal. An adaptive system will therefore not be significantly better than a well-designed static aerial.

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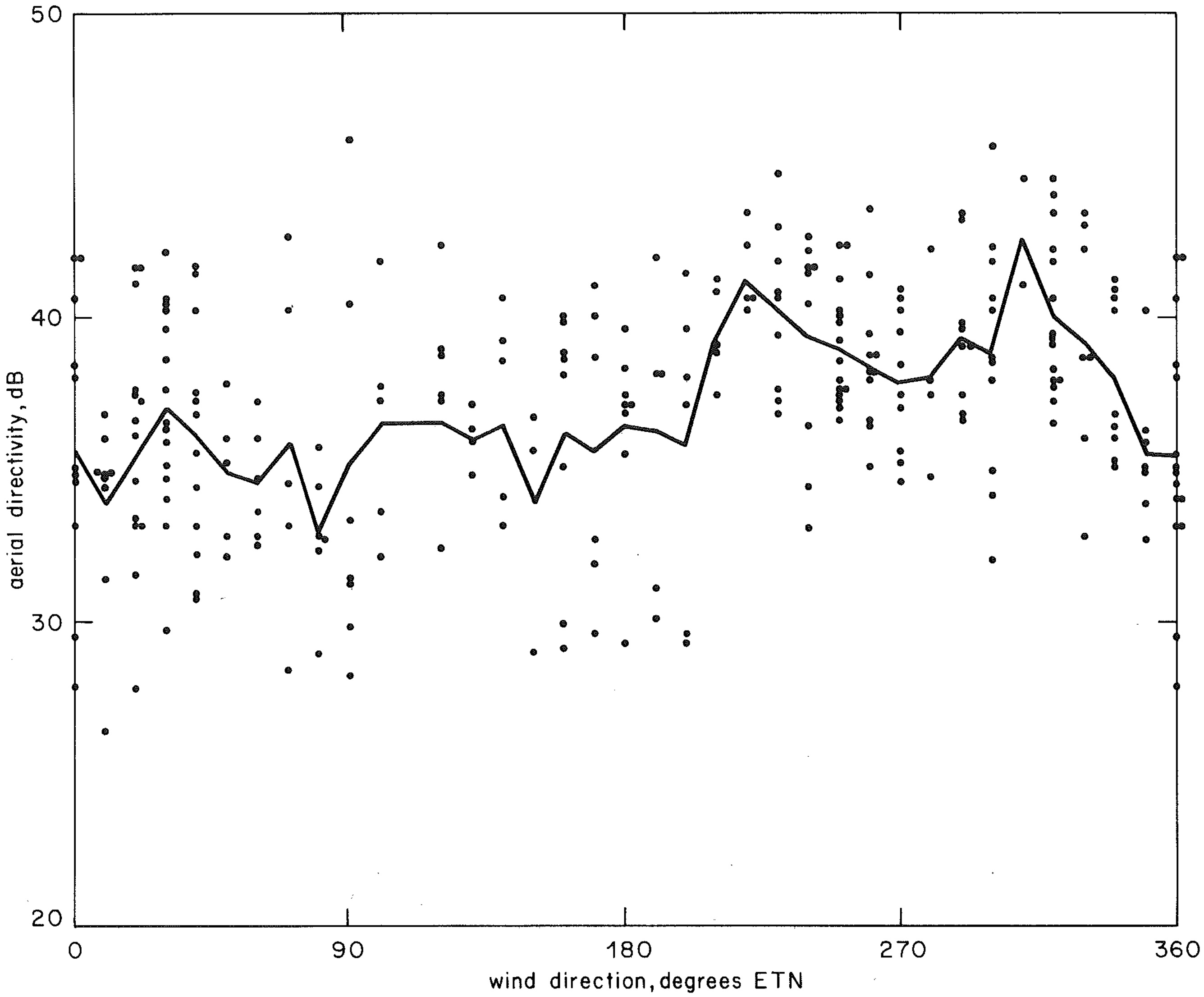

Fig. 14 - Effect of wind direction on aerial directivity

——— Mean value

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